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ELECTROMAZE PERFORMANCE OF GRADUATE STUDENTS IN PHYSICS AND AMERICAN STUDIES

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ABSTRACT

Seven electromaze problems were administered to physics and American Studies majors. There was a significant difference in the variabilities of the two groups on three of the problems with respect to trials and on four with respect to time. There were significant differences between the means of the number of trials for two problems. A high and significant correlation between time and number of trials was found for the physicists, but not for the American Studies subjects. The correlations between the Miller Verbal Analogies and the electromaze scores were not significant.

Electromaze Performance of Graduate Students in Physics and American Studies*

A new electric multiple choice test has been described in a previous paper (1). It was postulated that the device might be used as a non-verbal test of reasoning. In a preliminary study seven elctromaze problems were administered to graduate students in physics and journalism. Significant differences were found in the variabilities of the two groups with respect to the number of trials and the time. The differences between the means were, in general, not significant. The correlations between the electromaze and the Miller Verbal Analogies scores were low and not significant.

A second investigation was carried out during the Summer 1952, with two more groups of graduate students. The same seven problems were used. However, the directions to the subjects were modified, and the order of two problems was interchanged.

The Problem

As in the first study, the present experiment was designed to test three null hypotheses:

1. There are no significant differences between the means of the number of trials required to solve the electromaze problems by two populations of graduate students.
2. There are no significant differences between the means of the electromaze time scores for two populations of graduate students.
3. The correlations between the scores on the electromaze problems and the Miller Verbal Analogies Test are not significant.

A fourth hypothesis involving the product of the trials and time scores was also tested.

It was decided to reject the hypotheses at the five per cent level of significance.

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Procedure

The Sample Population

The subjects of the experiment were selected from two populations of graduate students at the University of Minnesota. The electromaze test was given during July 1952 to 26 physics and 28 Ameridan Studies majors. The subjects constituted approximately fifty per cent of the male students enrolled in the graduate school during 1951-52 in the two fields. All the subjects were natives of U.S.A. or Canada so that the Miller Verbal Analogies test could be used as one of the variables.

Administration of the Electromaze Test

As in the preliminary investigation, the subjects were tested individually. The testing procedure in the present study differed from the first experiment in two respects. First, the directions were greatly shortened and presented to the subject on a 4 x 6 card, as shown in the Appendix. Second, the subject was not given an explanation of the "clue" light, but told to "watch the orange light". Also, problems six and seven were interchanged.

The time and the number of trials were recorded as in the first study. Whenever the subject had a question or wanted some supplementary information he was told to reread the directions, or that he could not hurt the apparatus by trying any button arrangement. In general, the subject was left to his own devices. When the time on the simpler problems exceeded 10 - 15 minutes and it was evident to the experimenter that the subject was "lost", he was told to go on to the next problem. If the second problem was solved, then the subject was allowed to come back to the unsolved problem. In a few cases the subject was able to come out of the "blind alley" and reached the goal in a short time. Others simply gave up, saying that they could not think of any more moves. All but one of the physicists completed the entire series of problems. Eight of the American Studies majors were not able to solve one or more of the problems.

Each subject was asked at the conclusion of the test: "What do you think this device measures?", "Do you have any comments and suggestions about the device and procedures?" The comments were recorded. The subjects were also asked not to discuss the device with anyone.

All the subjects were paid at the prevailing hourly rate scale for graduate students at the University of Minnesota.

The Miller Verbal Analogies Scores

The Miller Verbal Analogies raw scores were obtained from the departmental offices. Form G was administered individually to the subjects who had not taken the Miller test prior to the present study. Two points were added to the scores on Form H in the range of 30 to 70, as recommended in the manual (2).

Results

Number of Trials

a. Successful solution of all problems

The statistical summary of the data on the number of trials by the subjects who were successful with all the problems is shown in the upper half of Table 1 of the Appendix. There was a significant difference in the variabilities of the two groups, as shown by the F-test, on problems 1, 2, 6. The differences between the means were statistically significant for problems 1 and 2, with the physicists taking the smallest number of trials for successful solutions.

b. Successful solution of some problems

Using the data on all the subjects who had completed a given problem the variabilities and means were compared for problems 1, 2, 3, 4, as shown in Table 2 of the Appendix. All the subjects completed the first two problems. There were significant differences in the variabilities and the

means of the two groups for problems 1 and 2. There was a significant difference in the variabilities of the two groups for problem 4. The analysis was not extended to the remaining problems since the number of unsuccessful subjects increased rapidly from problem 5 on.

Time

a. Successful solution of all problems

The means and standard deviations for the time scores of the subjects who had completed all the problems are shown in the lower half of Table 1 of the Appendix. There was a significant difference in the variabilities of the two groups on problems 1, 2, 5, and 7. The differences between the means were not significant on any of the problems or on the total score.

b. Successful solution of some problems

The variabilities and the means of the subjects who had completed a given problem were compared. There were significant differences in the variabilities of the two groups on problems 1, 2, and 4. The differences between the means were not significant. The statistical summary is reproduced in the lower half of Table 2 of the Appendix.

Trials and Time

The assumption was made that a good score on the electromaze would be inversely proportional to the total number of trials and the total time for the series. However, a comparison of the two groups on this criterion failed to show any significant differences between the variabilities or the means of the two groups.

Correlations Between the Miller and the Electromaze Scores

The product moment correlations between the Miller raw scores and the electromaze scores for both groups are shown in Table 3 of the Appendix. None of the correlations were significantly different from zero.

Correlations Between the Number of Trials and Time

The correlations between the total number of trials and the total time to solve all the problems are shown in Table 3. The correlation of .70 for the physicists is significant at the one per cent level; the correlation of .29 for the American Studies majors is not significantly different from zero.

Comparisons of the Samples on the Miller Scores

The 45 physicists who participated in both experiments were compared with 53 American Studies majors on the Miller Test. There were no significant differences between the variabilities or the means. The distributions of the two sets of scores were nearly normal. The physics and the American Studies majors who participated in the present study were also compared on the Miller scores. Again there were no significant differences between the variabilities and the means.

However, when the 20 American Studies students who had finished all the seven problems were compared with the eight who had not solved the series, the means of the two groups were found to be significantly different. The more successful group had a mean of 74.1 as compared with 67.9 for the other. There was no significant difference between the variabilities of the two sets of scores.

There was no significant differences between the variabilities and the means of the Miller scores of the physics and the American Studies majors who had completed all the problems.

Subjects' Reactions to the Test

The subjects' free responses to the query: "What do you think this device measures?", are reproduced in the Appendix. It is clear that the great majority of the answers were given in words and expressions commonly

associated with the definition and measurement of higher mental processes. The most frequently used words by both groups were: logic, logical, and systematic. Other responses mentioned more than twice were: problem-solving, flexibility, reasoning, mathematical, patterns, imagination. Four of the subjects thought that the electromaze performance was related to mechanical or laboratory aptitude, but one specifically negated the assertion. Only two subjects thought that the device did not measure anything and one believed that there was a great element of chance involved in the successful solution of the problems.

Conclusions

On the basis of the data it was reasonable to conclude that there were significant differences in the electromaze performance of graduate students in physics and American Studies on the first two problems.

From the low and non-significant correlation between the Miller and electromaze scores it was concluded that the two tests measure different abilities and aptitudes.

Discussion

There were significant differences between the trial variabilities of the groups on problems 1 and 2 in both investigations. However, the differences between the trial means on these problems were significant in the present study only. Hence, it is reasonable to assume that there was a real difference between the ability of the physicists and the American Studies students in deducing the meaning of the clue light, as measured by the trial count. This difference could be accounted for by the wide divergence in background, experience, and interests characteristic of the two test populations.

It is interesting to note that all the subjects finished problems 1 and 2, and that there were significant differences in the means and

variabilities in this case also. This fact appears to support the assumption concerning a real difference in the two groups to solve the two electromaze problems.

The fact that all but one physicist out of 26 solved all the problems, whereas 8 out of 28 in the American Studies did not complete the series appears to be significant. It is not unlikely that graduate work in physics places greater emphasis on experience and aptitude with respect to the ability to formulate new hypotheses and to test them systematically.

The low and non-significant correlation between the Miller and electromaze scores emphasizes the essential difference in the nature of the two tests. The electromaze was postulated to be a non-verbal reasoning test; the Miller test on the other hand is verbal by definition. However, since there was a significant difference between the Miller means of those who finished all the electromaze problems and those who did not, it is reasonable to suggest that both tests may measure some similar aptitude or experience.

The correlation between the total number of trials and total time was significant and high for both groups in the first experiment. In the present study the trials-time correlation for the physicists was nearly the same as before. However, the correlation for the American Studies group was low and non-significant. Whether or not this difference in correlations indicates a more systematic approach in problem-solving by the physicists is a question requiring further investigation. Since many of the subjects thought that the ability to solve the electromaze problems was related to "logical thinking" it is proposed to carry out an investigation with graduate students in mathematics. It is also planned to obtain ratings by research supervisors on a number of traits and to explore their relation to electromaze performance.

Summary

1. The electromaze was used to compare the performance of graduate students majoring in physics and American Studies.

2. There were significant differences between the variabilities and the means of the trials for the first two problems.

3. There were no significant differences between the means of time scores for any and all the problems.

4. The correlations between the electromaze performance and Miller Verbal Analogies scores were not significant.

5. All but one of the physicists completed the problem series; more than one quarter of the American Studies group could not solve one or more of the problems.

6. The correlations between the total time and the number of moves was significant for the physicists, but not for the American Studies group.

References

1. Kruglak, H., Schensted, C.E. & Self, H.C. An Electric Multiple Choice Maze. Technical Report No. 1, ONR Project NR192-041. Physics Department, University of Minnesota, Minneapolis. 1952

2. A Supplementary Manual for the Miller Analogies Test (Form H). New York: The Psychological Corporation

APPENDIX

Directions

1. The object of each problem is to make the bell ring.

2. The center button is an "eraser". Pushing this button will cancel all previous moves.

3. The buttons may be operated in any manner without hurting the apparatus. Operate the 5 buttons only.

4. Try to make the bell ring in the shortest possible time and with a a minimum number of button pushes.

5. Watch the orange light.

Appendix

Table 1

Means, standard deviations, F-ratios, and t-values for the electromaze problems

All subjects solved all the problems

Physics majors, N = 25; American Studies majors, N = 20

	Problems 1	2	3	4	5	6	7	Total
Statistics	Number of trials							
M-physics	25.68	22.12	99.72	58.00	356.8	248.0	263.4	1074
M-Am. studies	65.10	61.70	109.8	59.25	356.4	210.5	267.4	1130
σ-physics	27.20	20.93	160.6	80.65	322.5	214.0	265.0	638.6
σ-Am. studies	68.16	63.90	139.0	68.69	361.2	127.3	312.1	408.4
F-ratio	6.35**	9.42**	1.32	1.36	1.27	2.80*	1.40	2.42
t or v#	2.38#*	2.59#**	.22	.05	.00	.71#	.04	.33
	Time in Seconds							
M-physics	82.24	63.16	171.6	70.68	537.0	478.1	512.7	1915
M-Am. studies	94.75	86.85	192.7	83.45	384.9	581.4	409.6	1834
σ-physics	212.6	161.8	311.4	117.5	527.8	484.5	477.2	1239
σ-Am. studies	99.46	71.36	272.2	111.4	289.6	429.3	275.5	594.1
F-ratio	4.52*	5.09**	1.29	1.10	3.29**	1.26	2.97**	4.30**
t or v#	.26#	.64#	.23	.36	1.20#	.73	.19#	.29#

#Aspin and Welch Test, when variances are not homogeneous

**Significant at the one per cent level

*Significant at the five per cent level

Appendix

Table 2

Means, standard deviations, F-ratios, and t-values for the electromaze problems

N = number of subjects who solved the problem in question

	Problems 1	2	3	4
Statistics	Number of trials			
M-physics	26.62	22.19	98.04	56.46
N	26	26	26	26
M-Am. studies	64.64	67.25	109.9	101.8
N	28	28	27	26
σ-physics	27.07	20.53	157.7	79.45
σ-Am. studies	63.86	66.59	123.1	168.1
F-ratio	5.55**	10.49**	1.71	4.47**
t or v#	2.83#**	3.35#**	.30	1.22#
	Time in seconds			
M-physics	85.0	61.58	168.1	68.50
N	26	26	26	26
M-Am. studies	108.8	101.1	197.8	163.88
N	28	28	27	26
σ-physics	208.9	158.9	305.8	115.7
σ-Am. studies	126.2	68.59	253.9	301.2
F-ratio	2.75**	5.38**	1.45	6.77**
t or v#	.49#	1.15#	.38	1.48#

#Aspin and Welch Test, when variances are not homogeneous

**Significant at the one per cent level

*Significant at the five per cent level

Appendix

Table 3

Correlation matrix for trials, time, and Miller Verbal Analogies scores

Physics majors, N = 25			American Studies majors, N = 20	
Variables	Correlation coefficients			
	Miller Scores		X_t	
	Physics	American Studies	Physics	American Studies
X_1=trials to solve problem No. 1	.005	-.19		
X_2=trials to solve problem No. 2	-.15	.12		
X_t=trials to solve all problems	.24	.12		
Y_t=total time to solve all problems	-.02	-.09	.70**	.29

**Significant at the one per cent level

Appendix

What do you think this device measures?

Responses of Physics Majors

1. Probably doesn't measure much of anything.
2. Orderly thinking - no verbalization necessary.
3. Ability to analyze situations; reasoning ability.
4. Ability to react and to think things through.
5. Ability to systematically exhaust possibilities, some imagination.
6. Possibly mathematical problem-solving related to it.
7. Adjusting to situation, rationality, imagination, changing set.
8. Possibly related to logical ability.
9. Systematic approach.
10. Manipulative skill; catching on to combinations, abstract symbolism experience
11. Big element of chance.
12. Ingenuity, logic.
13. Ability to infer from data.
14. Observation.
15. Ability to change approach; logical thinking.
16. Orientation; flexibility; learning.
17. Logic.
18. Orientation to a new situation, laboratory skill, flexibility.
19. Follow logical sequence.
20. Observation, systematic approach.
21. Flexibility, mechanical aptitude, logic.
22. Memory, reasoning, symbolic logic.
23. Systematic pushing.
24. Learning, adaptability to new situations.
25. Methodical approach.

Responses of American Studies Majors

1. Emotional stability,
2. Intelligence.
3. Problem-solving.
4. Problem-solving; mathematical ability.
5. Ability to concentrate, logical elimination.
6. Ability to change theories.
7. Reasoning ability.
8. Patterns, relationships,
9. Pattern imagination - make order of chaos.
10. Logic, systematic approach.
11. Quick thinking, quick logical decision.
12. Possibly not much related to anything.
13. Adaptability.
14. Don't know - maybe logic and reasoning.
15. Insight.
16. Mathematical ability; logic.
17. Keen perception.
18. Reasoning, logic; not mechanical ability.
19. Can't say - maybe "raw intelligence".
20. Logic.
21. Hypotheses.
22. Observation; systematic approach.
23. Ability to set up and test hypotheses.
24. Logic; patterns; Flexibility.
25. Follow directions; attitude.
26. Logical approach; laboratory knack.